tain localities the same drift is present on both sides of the escarpment, passing over the interruption, and in other places the bluff marks the boundary between two glacial formations. Whatever did cause the escarpments was local; for they are limited in extent, and besides them no others with similar alignment exist reasonably near. The only methods ordinarily found are the erosion of sedimentary strata of various resistances, and faulting. The geology of the region is that of an old-land surface, of complex structure, composed of very ancient sediments and crystallines. This could not possibly give such an escarpment by simple erosion.

The field evidence, however, leads directly to faulting as the ultimate cause of the present topography. Here the physiographer must turn to the geologist for help. But having received his answer, certain problems of erosion are thrust upon him; and he must decide whether the faulting is recent, and if not, its age and the subsequent history of the surface. These I have not found treated in the literature of the country, nor more than hinted at in conversation with Continental geologists who are acquainted with the localities.

To the south of the escarpments the rocks are Cambrian, Cambro-Silurian and Silurian sediments, with some outcrops of the pre-Cambrian crystallines close to the fault. To the north are mainly crystallines, with two outcrops of Silurian close to the bluff. In most places where the escarpments are not accompanied by a waterway the surface deposits change abruptly. In other instances no change takes place.

From the physiographic standpoint, then, it appears that the fault is an old one, of unknown date, which brought weaker Silurian and Cambrian rocks against the crystallines. The down-throw was to the south, allowing that portion of the sediments which now remains, to drop. Since then the country has been reduced to base-level at least once, and probably a number of times; and any sediments which once extended northward over the crystallines have been eroded. The last cycle of changes has included re-elevation, revival of stream action, and etching out of the present topography in the less resistant Silurian and Cambrian, giving the appearance of a recent fault.

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*LIFE CONDITIONS OF THE OYSTER: NORMAL AND ABNORMAL.**

THE Committee are bringing their investigations to an end for the present, and they now state in this final report a series of the conclusions at which they have arrived. The details of the evidence upon which these conclusions are based will appear in a fully-illustrated memoir by Professor Boyce and Professor Herdman, which is nearly ready for publication. A good deal of that evidence has, however, been outlined in our former reports (at Ipswich, Liverpool and Toronto), and need not be now repeated.

Since last year's report, however, we have gone further into the question of the amount of copper and iron present in different parts of various kinds of oysters, with results which sustain the conclusions we had already arrived at.

We have also gone more minutely into the question of typhoid-like organisms, their occurrence in shellfish, and the differentiation of these from the *B. coli communis* on the one hand, and from the true *B.*

* Third and Final Report of the Committee of the British Association for the Advancement of Science, consisting of Professor W. A. Herdman (Chairman), Professor R. Boyce (Secretary), Mr. G. C. Bourne, Dr. C. A. Kohn and Professor C. S. Sherrington, appointed to Report on the Elucidation of the Life Conditions of the Oyster under Normal and Abnormal Environment, including the Effect of Sewage Matters and Pathogenic Organisms. (Drawn up by Professor Herdman, Professor Boyce and Dr. Kohn.)

typhosus on the other, with the following results:

BACTERIOLOGY OF SHELLFISH.

In one of our previous reports (B.A., Liverpool, 1896) we drew attention to the comparatively frequent occurrence of a group of organisms giving the reaction of the *Bacillus coli*, and also of a motile bacillus, which, owing to the fact that it did not behave like the Colon bacillus in all its reactions—*i.e.*, formation of indol and gas bubbles, approached somewhat the *B. typhosus* type. Shortly after the publication of that paper Dr. Klein drew attention, in the very comprehensive Local Government Board Report, upon 'Oyster Culture in Relation to Disease,' to the frequency of the presence of the Colon bacillus in oysters, and in one instance to the presence of a bacillus which, after most careful investigation, could not be distinguished from the bacillus of Eberth. Since that date we have continued our investigations upon the bacteria present in oysters, and have further extended them to other shellfish. We have examined, during the last year, 19 batches of oysters, 17 batches of mussels, 18 batches of cockles, 5 batches of periwinkles and 1 batch of whelks; these were obtained from shops in various parts of Liverpool.

Methods.—The methods employed were similar to those detailed in our Report previously referred to, except that we availed ourselves of the serum reaction, and we desire to express our thanks to Dr. Christophers, who especially undertook the investigation of the serum reaction in connection with all the 'coli' and typhoid-like organisms which were isolated in the Laboratory.

Results.—Oysters.—In nine out of the nineteen batches a colon-like organism was isolated from the interior of the oysters. In some instances there was almost a pure culture of the Colon bacillus, the Petri dishes giving a very characteristic odor. The reaction in the nine cases differed; there was the typical colon group, coagulating milk, forming indol and gas, and giving a decided acid reaction, as well as an abundant growth upon potato. There was also a group consisting of very active bacilli, not coagulating milk, not forming indol, occasionally forming gas, and in two cases giving rise to a slightly acid reaction in neutral litmus whey, and in three cases to an alkaline reaction. In each suspicious case the serum reaction was carefully tried, but always with negative results. We conclude that this latter group, although giving some of the reactions of the typhoid bacillus, cannot be regarded as identical with the true bacillus of Eberth.

Mussels.—The colon group is less frequent; some of the bacilla isolated coagulated milk, formed gas and indol, whilst others gave negative reactions, as in the case of the oysters.

Cockles.—A colon bacillus was not isolated. A coccus not liquefying gelatine, growing at a temperature of 37° C., and sometimes forming gas, was frequently met with.

Periwinkles.—As in the case of the previous group, a coccus was isolated.

Whelks.—From these a bacillus was obtained which formed gas at 37° C., did not coagulate milk nor produce indol, and only after four days produced a slight acid reaction in neutral litmus whey; it, therefore, resembled the second group found in the oyster.

These observations show the frequent occurrence of the Colon group of bacilli in such shellfish as we have investigated. Moreover, they clearly indicate that some of the organisms composing this group are more closely related in their reactions to the *Bacillus typhosus* than others are, although none corresponded to that bacillus

in all respects. It will be remembered that in our Liverpool Report (1896) we described the occurrence of the typhoid organism after various intervals of time in oysters which we had experimentally infected with typhoid material. To that report* we may refer also for a discussion of the results of washing infected oysters in a running stream of sea-water, and for a statement of the diminution of the number of typhoid organisms as the time of inoculation recedes. In our Ipswich paper † we had shown that oysters were able to live, and did live, under very impure conditions, and were able to make use of sewage matter as food. We also demonstrated (in 1895) by experiments that those laid down in the proximity of drains contained far more micro-organisms than such as were some distance off in purer water. Finally, in last year's report at Toronto,‡ we gave an account of the unhealthy condition of certain green oysters, of the association of the color with a leucocytosis, and of the presence of copper in the leucocytes.§

As the result of these various lines of investigation, and of the examination of oysters alive under both natural and artificial conditions on various parts of the British, French, Dutch and Italian coasts, we have arrived at the definite conclusions as to their natural history, chemistry and bacteriology, which are detailed below; and to which we have ventured to add some recommendations as to administrative and public health questions. We are convinced that all that is necessary in order that the oyster may be restored to its proper position in public estimation as a most useful, delicate and nutritious food-matter is that shellfish importing, growing and laying shall be conducted under proper supervision, and that the grounds and waters chosen for the purpose should be inspected and licensed by duly qualified scientific authorities.

* *Brit. Assoc. Rep.*, Liverpool Meeting, 1896, p. 663.

† *Ibid.*, Ipswich Meeting, 1895, p. 723.

‡ *Ibid.*, Toronto Meeting, 1897, p. 363.

§ See also *Proc. Roy. Soc.*, Vol. LXII., p. 30.

CONCLUSIONS.

1. There are several distinct kinds of greenness in oysters. Some of these, such as the green Marennes oysters and those of some rivers on the Essex coast, are healthy; while others, such as some Falmouth oysters containing copper and some American oysters re-bedded on our coast and which have the pale green leucocytosis we described in the last report, are not in a healthy state.

2. Some forms of greenness (*e. g.*, the leucocytosis) are certainly associated with the presence of a greatly-increased amount of copper in the oyster, while other forms of greenness (*e. g.*, the Marennes) have no connection with copper, but depend upon the presence of a special pigment Marennin, which may contain a certain amount of iron.

3. We see no reason to think that the iron in the latter case is taken in through the surface epithelium of the gills and palps; but regard it, like the rest of the iron in the body, as a product of ordinary digestion and absorption in the alimentary canal and liver.

4. We do not find that there is any excessive amount of iron in the green Marennes oyster compared with the colorless oyster; nor do the green parts (gills, palps, etc.) of the Marennes oyster contain either absolutely or relatively to the colorless parts (mantle, etc.) more iron than colorless oysters. We, therefore, conclude that there is no connection between the green color of the Huitres de Marennes and the iron they may contain.

5. On the other hand, we do find by quantitative analysis that there is more

copper in the green American oyster than in the colorless one, and more proportionately in the greener parts than in those that are less green. We, therefore, conclude that their green color is due to copper. We also find a greater quantity of iron in these green American oysters than in the colorless; but this excess is, proportionately, considerably less than that of the copper.

6. In the Falmouth oysters containing an excessive amount of copper we find that much of the copper is certainly mechanically attached to the surface of the body, and is in a form insoluble in water, probably as a basic carbonate. In addition to this, however, the Falmouth oyster may contain a much larger amount of copper in its tissues than does the normal colorless oyster. In these Falmouth oysters the cause of the green color may be the same as in the green American oysters.

7. The colon group of bacilli is frequently found in shellfish, as sold in towns, and especially in the oyster; but we have no evidence that it occurs in Mollusca living in pure sea-water. The natural inference that the presence of the Colon bacillus invariably indicates sewage contamination must, however, not be considered established without further investigation.

8. The Colon group may be separated into two divisions—(1) those giving the typical reactions of the Colon bacillus, and (2) those giving corresponding negative reactions, and so approaching the typhoid type; but in no case was an organism giving all the reactions of the *B. typhosus* isolated. It ought to be remembered, however, that our samples of oysters, although of various kinds and from different sources, were in no case, so far as we are aware, derived from a bed known to be contaminated or suspected of typhoid.

9. Consequently, as the result of our investigations, and the consideration of much evidence, both from the oyster-growers' and public-health officers' point of view, we beg to recommend:

(*a*) That the necessary steps should be taken to induce the oyster trade to remove any possible suspicion of sewage contamination from the beds and layings from which oysters are supplied to the market. This could obviously be effected in one of two ways, either (1) by restrictive legislation and the licensing of beds only after due inspection by the officials of a government department, or (2) by the formation of an association amongst the oyster-growers and dealers themselves, which should provide for the due periodic examination of the grounds, stores and stock, by independent properly-qualified inspectors. Scientific assistance and advice given by such independent inspectors would go far to improve the condition of the oyster beds and layings, to reassure the public, and to elevate the oyster industry to the important position which it should occupy.

(*b*) Oysters imported from abroad (Holland, France or America) should be consigned to a member of the 'Oyster Association,' who should be compelled by the regulations to have his foreign oysters as carefully inspected and certificated as those from his home layings. A large proportion of the imported oysters are, however, deposited in our waters for such a period before going to market that the fact of their having originally come from abroad may be ignored. If this period of quarantine were imposed upon all foreign oysters a great part of the difficulty as to inspection and certification would be removed.

(*c*) The grounds from which mussels, cockles and periwinkles are gathered should be periodically examined by scientific inspectors in the same manner as the oyster beds. The duty of providing for this inspection might well, we should suggest, be assumed by the various Sea Fisheries Committees around the coast.